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Army to Add Wheelbearing Performance Test In Specifications for Grease

A wheelbearing performance test has been developed to be incorporated into U. S. Army specification 2-108A for General Purpose Grease No. 2, the lubricant used in the wheelbearings of all Army automotive equipment, the Office of The Quartermaster General announced May 21st.

The performance test was developed through a co-operative program by the Office, Chief of Ordnance, working with the Grease Advisory Group, Co-ordinating Research Council, whose final report on this work will be published for circulation to industry this summer.

This will be the first time such a performance test has been incorporated with the specifications for a material of this type. Announcement is being made at this time, it was pointed out, so that producers of grease may be advised of the new proposed requirement in time to make any necessary adjustments in manufacturing procedure.

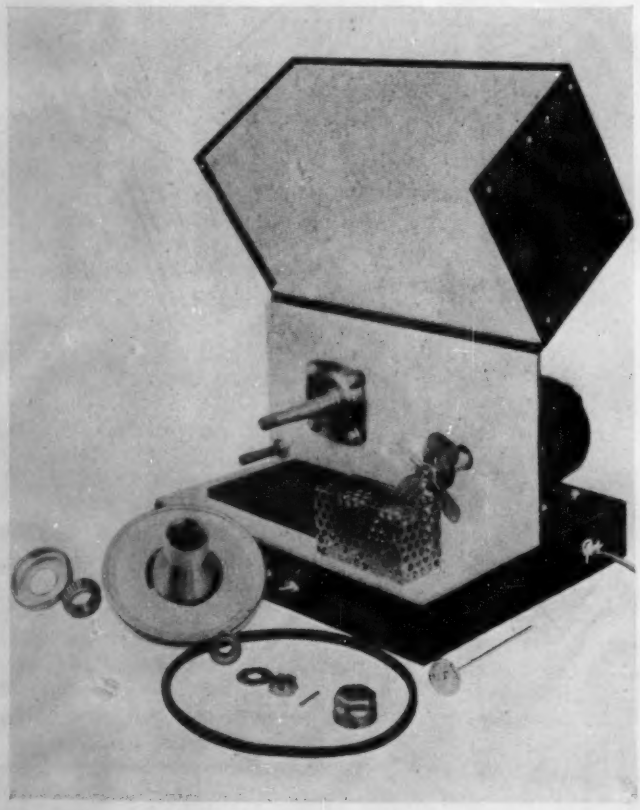
Details of the test are as follows:

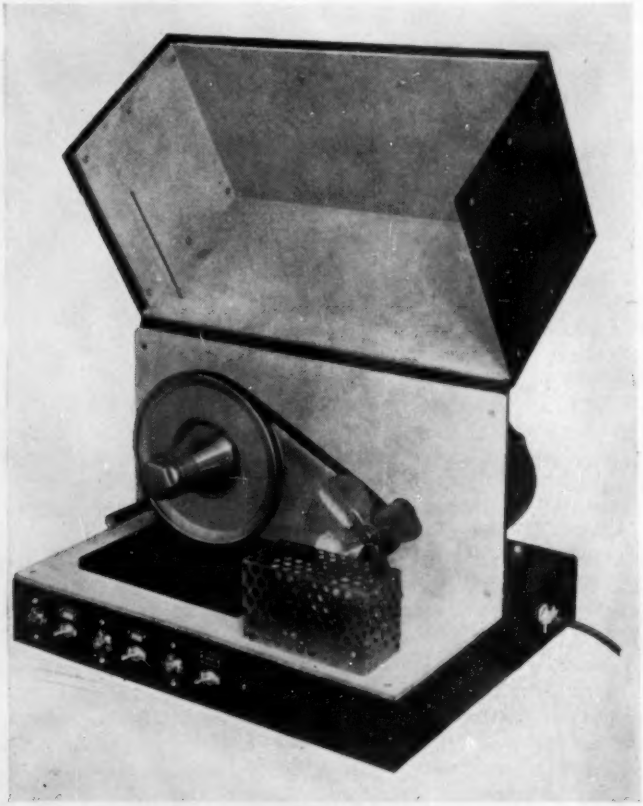
WHEELBEARING PERFORMANCE TEST

1. *Description of Apparatus*

The test equipment consists of a Ford wheel hub driven at 430 rpm by means of a V belt and motor and encased in an insulated box. A means for thermostatically controlling the temperature has been built into the base of the device to make it completely self contained. A fan on the motor

(Continued on Page 3)





Torque-Viscosity Characteristics of Lubricating Greases

By L. C. BRUNSTRUM, E. W. ADAMS AND E. E. ZIEGLER
Of Research Laboratories of Standard Oil Company (Indiana)

Presented at 12th Annual Meeting, N. L. G. I.

I. INTRODUCTION

Although many varieties of torque tests have been used to evaluate lubricants, the subject warrants our especial attention at this time because of the present widespread interest in the properties and behavior of greases in relatively slow moving bearings at temperatures as low as minus 100 degrees F. The conventional function of torque determinations at low temperatures is either the empirical evaluation of lubricants under a given set of mechanical and atmospheric conditions or the determination of the most drastic conditions under which a given lubricant will give satisfactory service. However, if improvement of the lubricants is to continue, we must relate our tests to the more fundamental properties of the products.

Two torque methods are commonly used, (1) the constant torque-variable shear method in which a given load is applied and the resulting speed measured and (2) the constant speed-variable torque technique in which the bearing is driven at constant speed and the resulting force is measured on the other bearing race. From a mechanical point of view the results by these methods should be identical. However, because of the peculiarities of lubricating grease consistency (apparent viscosity), the results are not comparable unless certain precautions are taken.

We will attempt to compare the type of results obtained by the two methods and to express the data in terms of viscosity. Shear rate, a variable which must be controlled in grease viscosity measurements, will be shown to require close control in torque measurements also.

II. DESCRIPTIONS OF LOW TEMPERATURE-LOW SHEAR RATE EQUIPMENT

The best constant torque device is that currently being recommended by the joint ABEC-NLGI Committee on low temperature torque tests[1]. Considerable co-operative work has eliminated most of the technique variables such as bearing packing method, extent and frequency of disturbing the sample while cooling and numerous small design features. Two major disadvantages of constant torque methods have been overcome to some extent by restricting the rate of rotation to 1 to 3 rpm, thus automatically narrowing the range of shear rate to an approximate variation of 1 to 3, and by reporting the data as "plasticity number" (torque x time).

To obtain a direct comparison of results by the two methods a tester was built which is capable of being operated at either constant torque or at constant shear rate. Conversion is accomplished by simply changing the drive, i. e., by using weights or a motor. Three bearings mounted on a horizontal shaft are used to minimize slight variations in bearing fits and grease packing.

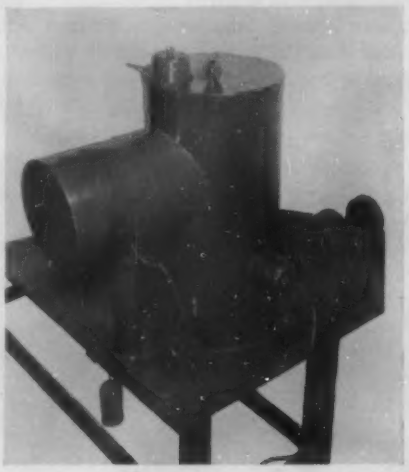
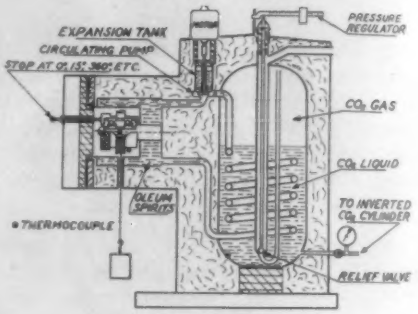


FIG. 1

Figure 1 is a general view of the tester as operated at constant torque. A collar fits over the outer races, tying them together so that they rotate freely as a single unit. By adding weights to a cord which runs over a pulley integral with this collar any desired torque may be applied in either direction to the bearing assembly. This loading arrangement eliminates the unknown and variable friction encountered when an outboard bearing is used to support the end of a shaft on which the test bearings are mounted. One, two or three eight-ball, No. 204 ball bearings can be installed with or without shields. An insulated cover which encloses the test bearing chamber is removable, allowing easy access to the bearings, and providing for visual inspection of the bearings in operation when desired. An adjustable stop located in this removable cover allows smooth application of the desired torque and automatic stopping after 15" of movement or at the end of any complete revolution.

FIG. 2 COOLING MECHANISM



Thermocouples (Figure 2) are located (1) in the center of the test bearing shaft, (2) in the enclosed air space 1/8" from the outer race retainer, and (3) in the cooling chamber itself. For refrigeration, the latent heat of vaporization of carbon dioxide is utilized. A suitable coolant, such as oleum spirits, is circulated by a small rotary pump through an annular jacket around the test bearings and also, by means of suitable tubing, through a chamber containing liquid carbon dioxide. The pressure in this chamber is regulated and the boiling point of the liquid Co_2 thereby adjusted until the bearing assembly reaches the desired temperature. A weight-loaded "pop-off" or pressure-relief valve is provided for this purpose. So that the valve will not freeze and become inoperable, it is located at the lowest point in the chamber in order that it will be covered by liquid as long as any is present. Once the required pressure is reached and the weight loading of the valve fixed, the liquid Co_2 keeps boiling at a constant temperature. Any small increase in temperature produces an increase in pressure sufficient to open the pressure-relief valve. The original conditions of temperature and pressure are promptly restored by the cooling effect exerted as more liquid boils off and gaseous Co_2 expands through the valve opening. Equilibrium conditions result from repeated opening and closing of the relief valve in this manner until finally a very small quan-

(1) Tentative Method for Determination of Low Temperature Torque Characteristics of Grease in Anti-Friction Bearings. ABEC-NLGI Committee

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Army to Add Wheelbearing Performance Test in Specifications for Grease

(Continued from Page 1)

shaft circulates air over the heaters and hub. The regular grease retainer is not used and in its place is a ring for catching any grease which leaks from the inner end of the hub. This is removable and provides a method of determining the grease loss. An apparatus meeting the proposed specification requirements is being manufactured by the Precision Scientific Company, 1750 North Springfield Ave., Chicago 47, Ill., and listed as their catalog No. 2652.

2. *Test Procedure*

A total of ninety grams of grease are used for each test. The bearings are carefully packed by hand with approximately five grams of grease (about 2.0 and 3.0 grams in the smaller and larger bearings, respectively) and the balance is placed in a uniform layer on the inside of the hub. A very thin film of grease is applied to the outer races contained in the hub. The ninety grams of grease fills the hub practically even with the bearing races and, with the exception of very fibrous greases, can be readily and uniformly distributed by use of a small spatula.

The leakage cup is placed in position and the large or inner bearing, packed with the grease being tested, is next placed in its proper position on the spindle. The wheel and outer or small bearing are then put on, followed by the loose fitting retainer washer and the castellated nut for holding the wheel assembly in place. The assembly is tightened until the wheel ceases to coast when spun by hand, the castellated nut is then slacked off until the wheel rotates quite freely without any play (approximately one-sixth of a turn). The hub is then locked in place by insertion of the cotter pin. After the hub cap is screwed on the V-bolt is finally put into place and the cover of the insulated box closed.

When the apparatus is thus assembled the motor and both heaters are turned on. Each test is run for six hours from the time the motor is started and the heat switched on. (In case of questionable results in a six-hour run a second test of sixteen hours duration can be made, the same requirements being imposed upon the lubricant. The need for the longer period of test will be found in rare instances only).

The temperature of the spindle is brought to and maintained at a temperature of 220 degrees F. This will be attained by an ambient temperature near the hub of approximately 235 degrees F varying somewhat with room temperature, air currents, etc. This temperature should be reached in a maximum of 30 minutes, 20 minutes generally being adequate.

At the end of the test the apparatus is dismantled while hot and an evaluation of the product under consideration is made according to the following criteria.

3. *Evaluation of Grease*

a. The apparatus, immediately at the conclusion of the test, is dismantled and the wheel inclined upon the bench, resting upon the edge of the pulley and outer hub. Flowage of grease from the hub shall not, per so, be cause for rejection, so long as the material is still of grease consistency. However, abnormal loss of grease consistency to the extent of becoming quite thin or "puddling" shall be cause for rejection.

b. Abnormal change of grease structure from the original shall be cause for rejection. (This refers to either smooth or short fiber grease assuming a very fibrous, ropey structure, "setting up," gelatinizing, or forming a dry brittle gel structure.

c. Leakage in excess of 10 grams of grease and/or oil into the grease retainer at the back of the hub shall be cause for rejection.

d. Any adherent deposit of varnish, gum, or lacquer-like nature upon the bearings or races which is in evidence after slushing for two minutes at room temperature in naphtha (as specified in ASTM Method D-91-40) for removal of the grease film shall be cause for rejection.

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tity of gas passes out at a steady rate. Inasmuch as a pressure change of 3 lbs/sq. in. corresponds roughly to a 1 degree F change in the boiling point of liquid CO_2, the device affords quite precise temperature control. It requires a minimum of attention and operates almost noiselessly without odor or objectionable waste products.

When the tester is operated at constant shear rate the drive consists of a one-twentieth horsepower synchronous motor turning 1800 rpm. and a 900:1 gear reducer, both mounted on a swivel arm. This arrangement provides inner bearing race rotation of 2 rpm. in either direction, which speed was selected because it corresponded with the 30-second interval specified by the AXS—and AN-G-3 tests for one revolution. Figure 3 shows this power drive rotated out of working position. Torque is read directly from a mercury manometer which is actuated by compressed air regulated by a needle valve attached to the torque string. The method of operation is shown schematically in Figure 4. This part of the device has been found very responsive. Its range may be changed by adjusting the lever arm attached to the torque string.

III. INTERPRETATION OF RESULTS

A. Torque-Time Relationships

As grease manufacturers we are interested in interpreting our results in terms of the fundamental properties of our products. Torque data have little meaning to a manufacturer of grease unless he can interpret them in terms of oil viscosity, soap content,

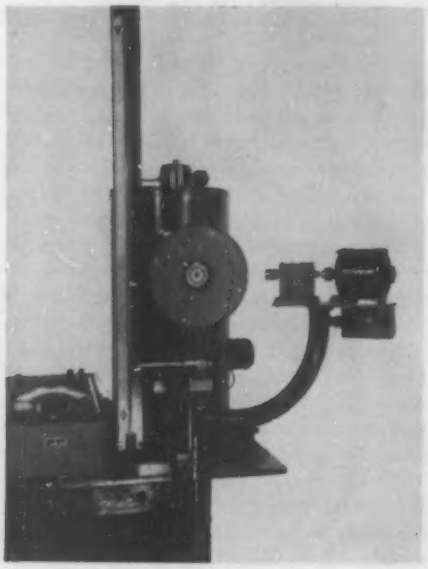
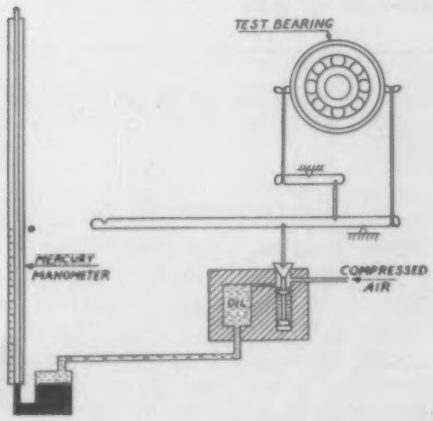


FIG. 3

etc. For example, to improve "channeling properties" of a grease we do not remove x "channel units," but rather we reduce the low sheer rate viscosity by decreasing the soap content and/or by lowering the oil viscosity. So with torque tests we must relate the data to apparent viscosity and finally to soap content and oil viscosity.

When a Newtonian lubricant is used, it is reasonable to assume that a twofold increase in applied torque would produce a twofold increase in rpm of the test bearing. In other words the product of torque and time for one revolution would be a constant. This is of the same nature as the coefficient of viscosity and in fact would be the coefficient of viscosity of a Newtonian liquid if expressed in cgs units. The dimensions

FIG. 4
SCHEMATIC DRAWING
OF
TORQUE MEASURING DEVICE



of torque x time are

$$\frac{ML^2}{T^2} \times \underset{\text{(torque)}}{T} \quad \underset{\text{(time)}}{} \quad \text{or} \quad \frac{ML^2}{T}$$

which may be written

$$\frac{M}{LT} \times L^3, \text{ in which } L^3 \text{ represents}$$

(viscosity)

constant bearing dimensions.

By analogy, when a non-Newtonian product is tested, the product of torque and time per revolution is proportional to apparent viscosity. This is also true of the "plasticity number" (torque x time) in the ABEC-NLGI method.

In constant torque tests selected from determinations at 1 to 3 rpm the average shear rate varies three fold and the actual rate (not considering the variation from point to point within the bearing) varies from zero to at least that equivalent to 6 rpm. We are discussing the range of shear rate and temperatures in which the products likely to be tested have almost a twofold change in apparent viscosity for a twofold change in shear rate.

It is obvious that the shear rate must be exactly controlled to get reproducible results from laboratory to laboratory. To be sure, this will not smooth out variations due to other causes, such as, for example, a rough bearing. Check results can never be obtained if the shear rate varies. In fact, identical results at other than identical shear rates are in error and dissimilar results at different shear rates may actually be checks.

CONSTANT SHEAR DATA

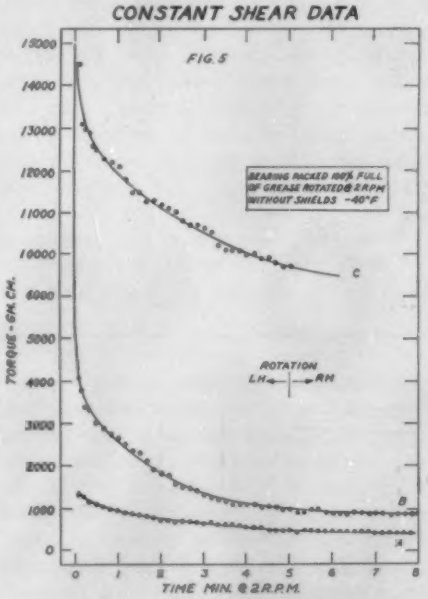


Figure 5 represents torque-time curves on samples A, B and C with the tester operating at constant shear. The highest manometer reading occurs just as the motor is started. This break-away torque is shown at zero time. Thereafter the manometer is read every ten seconds as the torque drops from the break-away to the equilibrium or running torque. In the case of samples A and B the motor was stopped after five minutes operation and started in the opposite direction (after a fifteen minute cooling period). No change in torque values are found after the bearing rotation is reversed.

The rapid decrease in torque during the first several revolutions is caused by excess grease being forced from the path of the balls and "working down" any structure the grease developed during the cooling period. Constant torque methods fail to provide this information because it is not possible to ascertain the instantaneous rates of rotation equivalent to the torque variations of the constant speed methods. Working the grease during the cooling period results in only the equilibrium values.

This curve can also be used to explain why the elaborate precautions specified in the present ABEC-NLGI constant torque method are necessary. Limiting the amount of grease used, running the bearing in before use, and intermittent operation while cooling all tend to make the break-away torque and equilibrium torque closer together, and nearer to reflecting grease viscosity.

Use of constant shear also has the advantage of the possibility of relating the results to apparent viscosity. When this is done the preliminary work carried out on difficult-to-control simulated service devices may be transferred to the more scientific laboratory pressure viscometer.

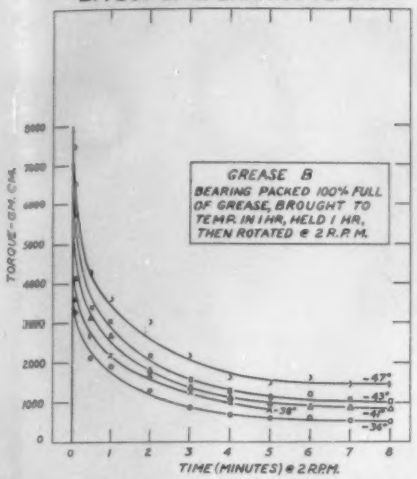
The shear rate in a complicated device can be estimated by testing both a grease and its oil in the device and in the pressure viscometer. There is only one shear rate for a given ratio of oil viscosity to grease viscosity for any given grease. The ratio obtained on the test device may be compared with the variable ratios obtained on the viscometer. The shear rate at which the ratios on the device and viscometer are equal may be taken as the effective shear rate in the device.

B. Torque vs. Temperature

One of the more important considerations is the effect of temperature on torque values of grease. In Figure 6 is shown a family of torque-time curves. It will be seen that small temperature changes produce quite large changes in torque. The equilibrium torque values may be plotted against temperature or may be converted to viscosity and plotted against temperature.

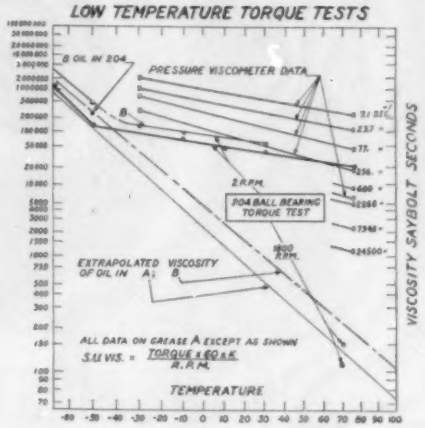
It has been shown that "plasticity number" or torque x time is related to viscosity. The equilibrium torque in constant speed

FIG. 6
EFFECT OF OPERATING TEMP.


GREASE B
BEARING PACKED 100% FULL OF GREASE, BROUGHT TO TEMP. IN 1 HR., HELD 1 HR., THEN ROTATED @ 2 R.P.M.
TORQUE - GM. CM.
TIME (MINUTES) @ 2 R.P.M.
-67°
-43°
-38°
-42°
-36°

devices is an excellent measure of viscosity and may be expressed as "plasticity number" or torque x seconds for 1 revolution simply by dividing torque by revolutions per second. However, torque x time values on a series of greases represent viscosities in some unknown units comparable only with other similar tests. By means of an arbitrary constant, it has been possible to convert these values to Saybolt viscosity, this scale having been chosen only because of its widespread use. In Figure 7 all of the data have been converted to Saybolt viscosity

FIG. 7
LOW TEMPERATURE TORQUE TESTS


B OIL IN 204
PRESSURE VISCOMETER DATA
2 R.P.M.
204 BALL BEARING TORQUE TEST
1800 R.P.M.
EXTRAPOLATED VISCOSITY OF OIL IN A; B
ALL DATA ON GREASE A EXCEPT AS SHOWN
S.U. VIS. = TORQUE x 60 x K / R.P.M.
TEMPERATURE
VISCOSITY SAYBOLT SECONDS

although none was obtained as such. The long lines are the extrapolated viscosity of the oil in sample A and sample B. These were converted from suspended level observations. The series of lines labeled "pressure viscometer data" were obtained as absolute viscosity and converted to Saybolt viscosity. Finally the lines marked "204 ball bearing torque test" were obtained as torque x time data and converted to Saybolt units by means of the arbitrary constant. Obviously this numerical value is applicable only to 204 bearings operated at 2 rpm but could be used in general according to the formula shown in the figure.

(To Be Continued)

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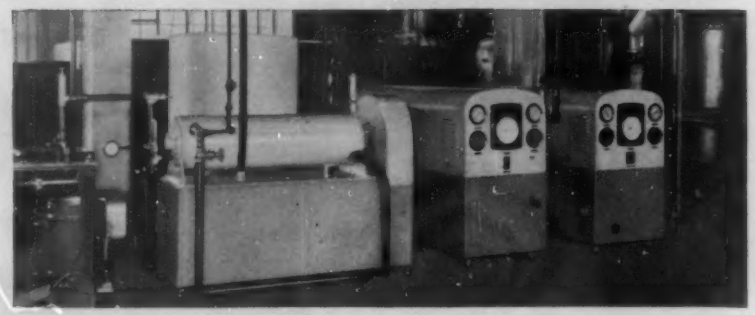

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TESTING ★ TOPICS

STEAM TURBINE OIL OXIDATION APPARATUS

A.S.T.M. Committee D-2 Report, 1943, Appendix II

IN determining the oxidation characteristics of steam-turbine oils, including those used for steam turbine gears, the oil sample is subjected to a temperature of 95° C. in the presence of water, oxygen and iron-copper catalyst, and the time required to build up a neutralization number of 2 in the oil sample is determined.

The turbine oil oxidation test can be used to demonstrate the deleterious effect of used oil, sludge and other contaminates on new oil life.

The apparatus consists essentially of an electrically heated thermostatically controlled oil bath of sufficient size to hold eight oxidation cells immersed in oil to a depth of approximately 350 mm.

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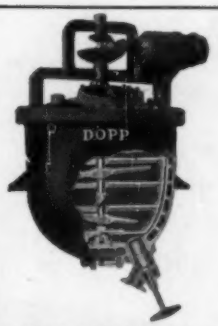

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